ANTS' NESTS

BY

Dr. AUGUST FOREL.

FROM THE SMITHSONIAN REPORT FOR 1894, PAGES 479–505
(WITH PLATES LV, LVI).

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A nest is a temporary or permanent, naturally or artificially formed hiding place, which serves as a dwelling for an animal and its family or for a more numerous society of animals. The nest is also intended, at the same time, for protection against enemies and against the inclemency of the weather and of the temperature. There are, however, not only purely natural nests (such as natural caves and hollows) and purely artificial nests (such as blackbirds' nests), but also, in many cases, mingled forms, where natural hiding places are completed by artificial help. Nests may also be divided into transient or season nests and permanent nests.

Now, in the case of animals which live in large societies, such as beavers, wasps, and ants, the nest becomes a complicated building or labyrinth. There are also elaborate and rough primitive nests.

The ants, or Formicidæ, form a great family of the insect order of the Hymenoptera. They number upwards of two thousand known species, distributed throughout the whole earth, which form about one hundred and fifty genera. All species of ants live in societies, and almost all display a peculiar so-called polymorphism; that is, every species consists, not only of a female, usually winged, and a male, usually winged, differing extremely from each other in the whole structure of their bodies, but also of other individuals without wings, which are offspring of the female sex, and are called "workers." The division, however, goes still further in certain species, the "worker" caste being subdivided into two kinds—differing greatly in their physical structure—"workers" and "soldiers." Between these there are species with intermittent workers, the largest of which resemble the "soldiers;" that is, form a phylogenetic precursor to the "soldiers."

Most of the female and male ants are winged, and copulate in the air or in the tops of trees; but at least one of the sexes is always winged. The new colonies are almost invariably founded by a pregnant female, or by several such, as has already been stated by Huber, and

[1] Translation of Die Nester der Ameisen. Von Dr. August Forel, professor in Zurich. Neujahrsblatt der Naturforschenden Gesellschaft zu Zurich, 1893.

has been clearly proved in recent years by MacCook, Lubbock, Blochmann, and others. These females live many years (eight to twelve years, according to Lubbock's experiments), and always remain prolific without renewed copulation. They are the mothers of the whole so-called ant colony, which, consequently, lasts many years and does not die out annually like the wasp colony. It follows from the facts stated that the ants must have permanent nests, and that these nests must display great variety, both of which inferences are correct.

The ants have, moreover, the peculiarity of changing their abode from time to time in order to move to a new one. They understand how to change their dwelling and how to build anew.

Many species of ants understand likewise how to colonize; that is, how to build new nests at a certain distance from their dwellings without leaving their old nest. It is in this way that mighty colonies, with numerous nests, are founded, resembling, to use Huber's words, the cities of one and the same empire. I have counted as many as two hundred immense nests standing close together in our European *Formica exsecta* NYL., and MacCook has counted as many as sixteen hundred still larger nests of one and the same colony of *Formica exsectoides* FOREL in the Alleghanies of North America. These latter ant kingdoms have, in all probability, a population of 200,000,000 to 400,000,000 inhabitants, all forming a single community and living together in active and friendly intercourse, while they are on hostile terms with all other colonies of ants, even those of the same species. Certain kinds of ants which live in trees form similar kingdoms by occupying numerous trees of the same forest.

In addition to this, ants frequently construct annexes to their nests—covered ways, subterranean passages, stations, and flying camps—in order to protect the plant lice which serve them as milk cows, and also for other purposes.

It is further to be remarked that there are courageous, warlike kinds of ants, whose nests are, consequently, open and easily discovered, while other kinds are timid and live in concealment, in many cases, because their colonies consist of only a few individuals. There are, besides, ants with good eyes, which make their nests above ground, and even on the boughs of trees, while there are blind and half blind kinds which live hidden deep underground.

As I have formerly asserted (Fourmis de la Suisse, 1874), the chief feature of ant architecture, in contradistinction to that of the bees and the wasps, is its irregularity and want of uniformity—that is to say, its adaptability, or the capacity of making all the surroundings and incidents subserve the purpose of attaining the greatest possible economy of space and time and the greatest possible comfort. For instance, the same species will live in the Alps under stones which absorb the rays of the sun; in a forest it will live in warm, decayed trunks of trees; in a rich meadow it will live in high, conical mounds of earth.

I will attempt to make a classification of the nests of ants, corresponding approximately to that which I formerly made with a view simply to giving an outline of the variety of the dwellings of ants. Of course, taking into consideration the above-mentioned features of ant architecture, it is impossible to be systematic.

I.—TAKING ADVANTAGE OF EXISTING CAVITIES.

Many ants use as nests simply the clefts and crevices of rocks and the space between two stones. They wall up and barricade the exterior of the clefts with sand, pebbles, and dry vegetable particles; they divide the surface, more or less, into chambers, and leave only one or a few doors (holes) open, to allow themselves egress. Many species of the genus *Leptothorax* live in this way, in small colonies, and *Plagiolepis pygmæa* LATR., *Cremastogaster sordidula* NYL., *Prenolepis longicornis* LATR., etc., in larger colonies, in the same manner.

Some such species have adapted themselves specially to mankind and occupy the walls of our houses. They know how to avail themselves there of the space between the stones; they bite away the mortar with all their might and carry it away in order to procure for themselves safe and warm lodgings in the neighborhood of our domestic stores, which they pillage thoroughly at the first opportunity. Such ants which have adapted themselves to the walls of our dwellings are *Lasius emarginatus* LATR., *Monomorium pharaonis* L. (imported into seaports from the Tropics), *Pheidole megacephala* FABR. These insects, as is well known, become house nuisances.

But other natural cavities are also made use of, especially those made by other insects. The species of *Leptothorax* and *Colobopsis* with us, those of *Polyrhachis* and *Cremastogaster* in tropical countries, know how to make use of the cavities of galls which have been abandoned by the gallfly for their nests.

Fig. 1, Plate LV, represents a stem gall from Delagoa Bay, Southeast Africa, one-sixth smaller than the natural size, which was inhabited by a colony of *Polyrhachis gerstäckeri* FOREL, and which was sent to me by our countryman, the missionary physician, Dr. Liengme, living there. The *Polyrhachis* had affixed some of their weaving to the inside, B. The egress opening made by the gallfly was the door of their nest. Cavities made by bark beetles in wood are used among us as nests by the species of *Liometopum* and *Lasius*, and especially by *Lasius brunneus* LATR., *Formica fusca*, etc. In the same way the space between the outer layers of the bark of trees (especially the conifers), the under side of the bark of dead trees, the under side of beds of moss, etc., are used as nests by the species of *Leptothorax* and other small ants. Ants also live frequently in hollow fruits, potatoes, and, above all, in large tropical fruits. Mr. Ortgies found the little *Brachymyrmex heeri* FOR. in the lower part of the pots of the tropical orchids in the Zurich hothouse, which were filled with moss, etc. My friend and colleague, Pro-

fessor Stoll, found the nests of *Camponotus atriceps* SM., race *stercorarius* FOREL, constantly under the dried excrement of cattle, and even inside of it, in Guatemala.

Père Camboué, in Antananarivo, Madagascar, sent me a stalk of *Solanum auriculatum*, the soft marrow of which, excavated and divided nto compartments, served as a nest for *Technomyrmex albipes* SMITH. In this case the gnawing capacity of the ants had made the natural object serviceable. A portion of this nest is represented in fig. 2, two-thirds of natural size.

Dr. Göldi, in Rio de Janeiro, sent me several specimens of *Camponotus cingulatus* MAYR., a very handsome, rather large ant, as the regular inhabitant of the hollows (internodes) of the bamboos there. Père Camboué, in Antananarivo, sent me *Prenolepis ellisii* FOREL from the hollow stalks of one of the Malvaceæ, in which it lives. Major Yerbury, of Ceylon, sent me, by Mr. Wroughton, *Camponotus reticulatus* ROGER, with its nest, which was also in a hollow stalk. Mr. Wroughton, divisional forest officer at Poonah, India, sent me the nests of a very small ant, *Cardiocondyla wroughtonii* FOREL, which he had found in the space between the two surfaces of the leaves of a tree (*Eugenia jambolana*), the parenchym of which (the green of the leaf between the exterior membranes) had evidently been devoured by a very small caterpillar. This nest of *Cardiocondyla wroughtonii* is represented in fig. 3 by Mr. L. Schröter.

The well-known ant nests in the hollow acacia thorns of tropical lands also belong to this class; but more on this subject hereafter.

2.—EARTH NESTS.

Earth is the most usual material for the nest building of ants. It is well known (Gould, Huber, etc.) that the ordinary earth structures (mounds) of many of our ants are created by the workers mining under ground after rainy weather, bringing the wet particles of earth to the surface of the ground and pressing them into walls and vaults by means of their mandibles and forelegs, using at the same time blades of grass, etc., as pillars and inside walls. In this way are made the well-known labyrinths, which I myself have watched innumerable times. It is, however, an unsolved problem whether really, as Huber thought, water alone always suffices as cement for the earth or whether it is not in some cases mixed with a secretion of the glands of the ants. The great firmness of certain structures, for instance those of *Lasius flavus*, gives some probability to the latter supposition, particularly when we consider the fragile character of the structures of other kinds of ants.

Earth nests may be divided into three classes:

(a) *Nests which are entirely excavated.*—In this case passages and chambers are simply excavated in the ground, without the particles of earth which are dug out being worked up into an artificial upper structure; they are merely thrown away. There are many kinds of ants

which mine only in this way, as, for example, *Ponera contracta* LTR., *Myrmecocystus*, all the *Dorylides*, *Aphænogaster subterranea* LTR., and, in general, most of the blind and half-blind species. Besides these many other species do it occasionally, such as *Formica fusca* L., *Formica rufibarbis* F., *Tetramorium cæspitum* L., species of *Myrmica*, etc.

One variety of the mined nests consists of those in which the ants heap up the excavated earth in banks around the openings of the nest so that crater-shaped openings are the result. This occurs most frequently in sandy soil. These banks are not genuine upper structures, although they often resemble them closely. We find them in the case of *Messor structor*, *Messor barbarus*, species of *Pheidole*, *Acantholepis frauenfeldi*, *Pogonomyrmex*, etc. A peculiar variety of this class is formed by the crescent-shaped mounds of *Messor arenarius* FAB., first noticed by me in the South Tunis desert near Cabes, which consist of coarse but very perishable globes of sand. At certain times the apertures of the *Messor* nests are, in addition, surrounded by mounds composed of the hulls of the seeds which have been gathered, which hulls have been thrown out of the nests. The little *Cardiocondyla elegans* EM. and *stambuloffii* FOREL make small nests in the sand on the seashore.

The subterranean structures of some kinds of ants are, in certain cases, extremely interesting. Certain species dig passages which go down very deep and branch off laterally, forming subterranean corridors, and in many cases leading to root plant lice (*Lasius flavus*) or serving for other purposes. The underground hunts of the species of *Dorylus*, or visiting ants, are partially carried on in this manner. These are blind robber ants, which carry on an underground hunt after all conceivable ground insects, as I myself have observed in Tunis. They are also called "visiting ants," because they frequently make a sudden attack at night upon dwelling houses and destroy all the vermin in them.

The species of *Messor* (Europe), *Pogonomyrmex* (America), and *Holcomyrmex* (India) construct under ground, at a considerable depth (often at the depth of a yard), very large chambers or granaries, in which they store the seeds which they have gathered. In the same way the species of the American genus *Atta* excavate extremely deep and extensive passages and make immense chambers, in which they store the leaves which they have cut from trees, in order to lay off upon them the fungus gardens from which they supply themselves with food. This discovery, which was first made by Belt and subsequently declared by MacCook to be incorrect, has been recently confirmed by Dr. Möller, of Blumenau, in its full extent and by superb experiments.

A great deal of interest is likewise attached to the underground hunts carried on by the ants of the genus *Lobopelta* in India, after the termites, according to the careful observations of Mr. Wroughton. They feed upon these white ants, and pursue them in their own pas-

sages. I conjecture that the same thing is true of the various species of the genus *Leptogenys*, and that they use their long, thin, pointed, sickle-shaped jaws, which bear a strong resemblance to a curved needle, to pierce the termites, which they then devour by the aid of their comparatively powerful under jaw.

(b) *Nests under stones.*—As is well known, wherever there are stones on dry declivities, etc., innumerable ants' nests are found under them. The stone serves as a roof, under which are the most beautiful corridors and chambers. Under these lies the mined nest. The stone serves, above all, to produce a speedy warming by means of the rays of the sun. The ants under it are always in the highest story, in damp or cool weather, as soon as the sun shines or begins to penetrate. As soon as the sun disappears the insects go below. They also go below when the sun shines too strong.

The same species which mine, and which build earthen structures above ground, also live under stones as soon as they find any. The stone must be neither too small and thin nor too thick and large. Stones of 2 to 15 centimeters in thickness are the most desirable, according to the size of the ants and the extent of their colonies. They allow the best regulation of the heat for the brood.

The species of *Lasius*, *Formica*, *Myrmica*, *Tetramorium*, *Plagiolepis*, *Pheidole*, *Camponotus*, *Aphænogaster*, *Bothriomyrmex*, *Tapinoma*, and other genera, are found in swarms under stones among us in Europe. There are few genera of ants that never live under stones.

(c) *Earth structures above ground.*—Many kinds of ants are excellent masons, but by no means all. It is easier to mine than to construct walls, vaults, and pillars.

I advise everyone who wishes to see one of the most beautiful displays of animal instinct and animal intelligence to equip himself with an umbrella, and with patience, on some warm day in May, when it begins to rain after a drought, or when it has just stopped raining, to repair to a meadow, and there, with the greatest perseverance, to watch attentively the surface of the ant-hills and the actions of their occupants. He must at the same time watch closely individual ants and their work. He will then admire the skill and foresight of these insects, and will see how the little architects and masons understand how to turn every blade of grass, every stalk, every leaf, to account, by means of their earth mortar, in the erection of vaults, pillars, walls, etc. In this manner are made those no less numerous than wonderful earth labyrinths which serve the ants in our meadows as conical superstructures. Our fig. 9 represents a fragment of the mound of an earth nest of *Lasius niger*. It can be seen how blades of grass and leaves are used in the masonry as pillars, arches, etc. The drawing, which is two-thirds of the natural size, was made by Mr. L. Schröter, like all the others, from the original piece, which I had hardened with a solution of silica. I need not add that a mined nest always lies under the superstructure

of the mound-building ants. What purpose does the latter serve? Judging from my own observations, the same purpose as the stones, to wit, to procure warmth for the brood. The grass springs up in May, and with it the ant mounds. These afford protection against the dampness and the shade of the primeval forest; for such is a meadow to the ants. Up there, under the roof of the mound, the rays of the sun are felt. We have in Europe a small ant (*Tapinoma erraticum* LATR.) whose perishable earth structures, first described by me, can, to all appearance, serve no other purpose. It builds hastily around the blades of grass a comparatively very high and steep mound of earth, which consists of little more than the upper, superficial, thin vault. Inside there are often only a few wretched thin chambers, especially where the grass is thick. The ants hold their brood partly in their upper jaws, partly lay them on leaves. They crowd together under the mound to warm themselves in the rays of the sun. After the harvest the mounds of the *Tapinoma* disappear, while those of the other ants remain standing. The latter, however, also become more and more flattened as autumn approaches. Our fig. 12 represents the perpendicular cross section of a nest of *Tapinoma erraticum* LATR., from Vaux, Canton Vaud, Switzerland, which was strengthened and preserved by me by means of a solution of silica, and is now in the Entomological Museum of the Federal Polytechnikum. Mr. L. Schröter has drawn the nest of two-thirds of the natural size. D, the temporary earthen cupola; Min, the beginning of the underground mined structure.

Among us mounds of earth with labyrinths are built by all the species of *Lasius*, with the exception of *Lasius fuliginosus* LTR., *brunneus* LTR., and *emarginatus* OL.; also by *Tetramorium cæspitum*, the species of *Myrmica*, several of *Formica* and *Camponotus*, and the species of *Tapinoma;* and in Tunis by *Monomorium salomonis*, *Aphænogaster striola*, *sardoa*, *testaceopilosa*, *crocea*, etc. The best artist is the most common of all ants, *Lasius niger* L., which swarms in all our gardens. This ant also constructs covered passages along the stalks of plants, where in this way it walls up its plant lice and cochineal kermes in artistic stalls. The species of *Myrmica* frequently build earthen stalls around the plant lice on the stalks of plants without putting them in communication with the ant-hill by a covered way.

In the island of St. Thomas I saw earthen structures made by *Solenopsis geminata* F. In Australia the large species of the genus *Myrmica*, which are 20 to 28 millimeters long, build immense nests of earth.

A seed-harvesting ant in Colorado, *Pogonomyrmex occidentalis* CRESSON, builds a very peculiar and isolated variety of the earthen mounds. It plasters or paves the whole upper surface of its earthen mound uniformly and in mosaic with a layer of small white stones, which, according to MacCook's observations, it frequently brings from a great depth in the ground. The still unknown object of this paving is prob-

ably the same as that of the earthen mounds in general. It is extraordinary that the little paving stones are placed side by side with great regularity like a street pavement, while the interior of the cupola contains no stones whatever. MacCook has even seen upon these mounds stones containing fossil remains and native gold. Mr. Henry de Saussure, of Geneva, made similar observations before MacCook among the genuine *Pogonomyrmex barbatus* i. sp., SMITH, but did not publish them.

3.—WOOD NESTS.

There are also woodcutters among the ants, and in not a few cases the same species knows how to make earthen structures and how to hollow out wood, as, for instance, our *Camponotus ligniperdus* LATR.

The best woodcutters are those species of the genus *Camponotus* MAYR, which have a short, broad head, rounded off in front, especially the subgenus *Colobopsis* MAYR.

These ants frequently bore with their short, powerful jaws into the very hardest wood, and construct secure and elegant labyrinths for themselves in it. This is the case with *Camponotus pubescens* in Wallis and Tessin, and *Camponotus marginatus*. The latter bores into the softer layers of the wood when they are somewhat decayed and lets the harder part remain, so that its nests are more concentric around the center of the bough or trunk in their arrangement. I have noticed them in cherry trees and Paulownias.

The smaller and very timid species of *Colobopsis* build themselves nests in the hardest wood. These nests open outward by only a very few small apertures, which are concealed by the irregularities of the bark of the tree. These apertures are kept closed by the head of a "soldier" sentinel, who permits only friends to enter. The soldier's head is broadened and rounded off in front, evidently for this very use. The rounded surface (front view in fig. 11, magnified ten times) is rough, of a dull-brown color; the feelers are planted back of the rounded surface, so that the latter presents no hold and blocks up the entrance to the nest like a living stopper. I first observed this fact among our *Colobopsis truncata* SPIN. at Vaux, Canton Vaud (fig. 13, drawn four-thirds of the natural size), but the similar structure of the head and the habit of living in trees, which characterize the other species of *Colobopsis*, lead us to infer that they live in the same way.

Fig. 13 represents a portion of the original piece of a nest of *Colobopsis truncata* discovered by me in a very hard, dead bough of a pear tree. B is the bark of the pear tree; Ch is the chambers and passages of the nest; O is the exterior opening of the nest; behind it, in the gallery of egress of the nest, stands a *Colobopsis* "soldier" as a sentinel, keeping the door closed with his head. At W are seen two *Colobopsis* workers, one hastening toward the door from the outside, the other standing in the nest. The soldier will go back into the nest for a moment in order to let the first worker come in (I have noticed this

among the living ants). That the part played by the *Colobopsis* "soldiers" is that of a living stopper is further proved by the fact that there are comparatively few of them, and that in contrast to the workers they hardly ever go out. Fig. 19 represents a "soldier," still more magnified, standing at the door of egress.

Those species of *Camponotus* which live in a similar way, such as *Camponotus marginatus* LATR., display the beginning of a similar rounded surface on the front part of the head, and always have a large-headed sentry at the door.

Leptothorax acervorum F. cuts small, very simple nests, spread out flat, with few chambers in the outer layer (the cork layer) of the bark of the tree. Fig. 5 represents such a nest two-thirds of the natural size in the bark of a fir.

4.—COMBINED STRUCTURES.

The structures heretofore described are combined in a variety of ways.

For instance, the hollow stalk of a large Arcangelica is filled from top to bottom by *Lasius niger* with small earthen chambers and occupied by them. Decayed trunks of trees are made use of by ants which elsewhere build in the ground, excavated, and worked up into nests by *Lasius niger*, *Lasius flavus*, *Formica fusca*, *Myrmica lævinodis*, etc. Here wood dust and earth are used as mortar in the construction of chambers and galleries. *Formica rufa* L. excavates the softer portions of the wood in half-decayed trunks of trees and builds in them labyrinths which form a part of its nests.

Lasius brunneus LATR. lives habitually in half-rotten trunks of trees and beams, after excavating the moist, decayed wood. It also lives in decayed woodwork in our houses, as do likewise frequently *Lasius umbratus* NGL.

The architecture of the group of forest ants, *Formica rufa* L., *pratensis* DE GEER, *truncicola* NYL., *exsecta* NGL., and *pressilabris* NYL., as well as of their North American relatives, *F. exsectoides* FOREL, *integra* NYL., *obscuripes* FOREL, etc., is, however, more imposing and more interesting.

These ants mine the ground, but cover their nests with dry vegetable matter of the most varied kinds—pine and fir cones, dry leaves and pieces of wood, snail shells, little balls of rosin; blades of grass, in a word, with every kind of round and cylindrical materials. With these they build the well-known immense mounds, with their singular framework and the indescribable interior labyrinth, the most thoroughly perforated part of which is in the middle, at about the level of the ground. Earth serves partially as cement. The openings of the nest are carefully closed with small pieces of wood at night or when it is raining. They are opened by the workers in the morning and generally in warm, fine weather.

The mound is gradually enlarged and strengthened by materials dragged to it. It protects the interior perfectly against cold and rain.

Formica rufa i. sp. of the fir woods uses chiefly fir leaves; *Formica pratensis* of the meadows builds flatter mounds and uses more pieces of wood and blades of grass, pieces of dry branches, etc.; *Formica exsecta* uses more particles of dry leaves, etc.; *Formica sanguinea* LATR. builds mounds composed of the above-mentioned materials and earth; its work is partly that of a carpenter and partly masonry; the latter, however, which is executed by the "slaves" (*Formica fusca*), usually prevails.

It is impossible for us to describe everything, and we refer our readers to Huber's admirable description of the way in which the forest ants and the earthen-mound ants build their nests. It may well be said that almost every species—either in earthen structures, in wood nests, or in combined structures—has its peculiarities with regard to the quality of the material, the fineness of the grain, the shape and arrangement of the mound and the labyrinth, the comparative thickness of the walls, the size of the chambers, etc., so that the species may frequently be known by the structure.

Still the ants often rob one another's nests, and this frequently renders it difficult to recognize the architect.

There are species, it is true, whose architecture can hardly be distinguished, as, for instance, the little species of *Myrmica*.

5.—PASTEBOARD NESTS AND SPUN NESTS.

I have already, in the Mittheilungen of the Swiss Entomological Society, Vol. VIII, part 6, 1891, given some information with regard to the singular nests which are now to occupy our attention. A well-known European species, *Lasius fuliginosus* LATR., builds peculiar pasteboard nests, which Huber erroneously thought to be excavated in wood, while Meinert, Mayr, and others, including myself, have demonstrated their true nature beyond a doubt. They are composed of the finest particles of wood dust or of earth and small stones, which, by means of a viscous substance secreted by the ants, are worked up into so strong a pasteboard (see Forel, Fourmis de la Suisse, pp. 181–187) that the partitions between the excavations are extremely thin (as thin as visiting cards). These nests are mostly found in hollow trees. That they are not excavated, but are composed of pasteboard, I have clearly shown by microscopic cuts. Meinert first called attention to the fact that in *Lasius fuliginosus* the glands of the upper jaw are extraordinarily large, and conjectured that they are the glands which secrete this viscous substance (cement). In fact a comparative physiological study of this gland which Wolff ("The smelling organ of bees") erroneously designated as the smelling-mucous gland, shows that a discovery which has been misinterpreted by Wolff is of special value. The substance secreted by this gland, both in bees and in ants, and

also the secretion of the posterior glands of certain ants (the *Dolichoderides*, with whom it serves as a weapon for smearing the faces of their enemies), is immediately decomposed at the first contact with the air, with a violent production of gas bubbles and the development of an aromatic odor which is very peculiar. As soon as this chemical decomposition is completed the residue of the secretion is transformed into a resinous, viscous mass, which is very sticky. There is no doubt in my mind that the viscous substance formed in this way is not a smelling mucus, as Wolff by a very far-fetched explanation, which is untenable for many other reasons, would have it, but forms the cement with which the nests and many other things are welded together.

What is still too little known, however, is the manner in which a genuine phylogenetic evolution converts this gland cement gradually into spun threads. The pasteboard of *Lasius fuliginosus* LATR. is very rich in wood dust or earthy matter and very poor in cement, so that it is very brittle. There is a drawing of it in my Fourmis de la Suisse, Pl. II, figs. 32 and 33. The pasteboard which *Liometopum microcephalum* PZ. manufactures in the innermost hollow of venerable but, nevertheless, strong, handsome, hard, large trees, and which is also composed of wood dust, is somewhat less brittle. They make it in oaks, poplars, apricot trees, etc., in southeastern Europe. Mayr gives a drawing of it, taken from a photograph, in the Proceedings of the Imperial Royal Zoological and Botanical Society of Vienna, June 1, 1892, Vol. XLII, Pl. V, fig. 7. A great many species of the genera *Cremastogaster* LUND and *Dolichoderus* LUND build only pasteboard nests on the boughs of trees, and these nests vary very much in their nature. In some cases the pasteboard is harder and more brittle, resembling wood, as among the species just described; in other cases it is thinner and more elastic or flexible, but at the same time has much greater power of resistance, and is much more like paper or pasteboard, like that of wasps. *Cremastogaster stollii* FOREL, of Guatemala, builds very peculiar galleries of pasteboard along the trunks of trees between the projecting portions of the bark. They were discovered in these galleries by my friend, Professor Stoll, who communicated this circumstance to me. In *Cremastogaster ranavalonæ* FOREL, of Madagascar, the pasteboard of the inside of the large, round, tree nest, is thicker and more brittle; that of the outer portion is always thinner, more elastic, and finally, in the outermost layers, even perforated, having a reticulate appearance, somewhat like loosely woven packing cloth. The nest of *Cremastogaster ranavalonæ* is represented in my "Formicides de Madagascar" (from Grandidier's Natural History of Madagascar, Vol. XX, part 28, Pl. VI, fig 4, 4*a*, and 4*b*, and Pl. VII). The nest of *Dolichoderus bispinosus* OLIV., which is composed of the seed hairs of a tree of tropical America (the wool tree, *Bombax ceiba* L.) woven together with gland cement, is very similar in appearance to the outer portions of this nest, but still more coarsely perforated and more net like. Fig. 18 represents a small piece

of this substance microscopically magnified. Fib represents the vegetable filaments, which are only moderately dismembered, so that their structure may easily be seen; Cem is the ant cement, the color of which varies from yellowish to brownish, and which can be recognized by its shapelessness and its color; Mesh represents the empty meshes of the network. Thanks to the coarseness of the substance, which is, consequently, in an almost unscathed and unpulverized state, the ant cement can be better distinguished from vegetable building matter in this case than in the other kinds of ant pasteboard.

Fig. 15 represents, in one-third the natural size, the photographed nest of *Dolichoderus bituberculatus* MAYR, of Bangkok, which was sent to me by the late lamented and well-known turner, Mr. Heinrich Sigg, of Zurich. This nest is composed of a compact (not perforated) but fine-grained pasteboard, greatly resembling that of the nests of the common wasp (*Vespa germanica*), but stronger. A section of the nest was taken off perpendicularly in order to show the structure of the interior. The nest is resting in its natural position on the bough where the ants had placed it. It can be seen how the small branches and leaves of the tree, glued together with pasteboard, are incorporated into the nest, and how the main bough serves as an axle to support the structure. It can be further seen how the labyrinth, constructed of pasteboard, is built more or less concentrically around the bough.

Some species of the genera *Camponotus* (*C. chartifex* SMITH, *traili* MAYR, *fabricii* ROGER, etc.), in South America, and *Polyrhachis*, in the East Indies, manufacture a very similar pasteboard. Fig. 4 represents a nest of *Polyrhachis mayri* ROGER, of Ceylon. The whole nest of most of the species of *Polyrhachis* consists of a single cavity of the size of a walnut or of a hen's egg, while the nests of other ants are, for the greater part, divided into chambers and passages. The egg-shaped nest of *Polyrhachis mayri*, which I received from Major Yerbury, of Ceylon, through Mr. Wroughton, stands simply like the cocoon of the silk-worm, on a leaf. The pasteboard of which it is composed resembles that of a *Cremastogaster* nest, but is very weak and fragile, being made of vegetable particles slightly glued together with gland cement. A silk thread has never yet been discovered in any of them. The cement is in the form of yellow or brownish flakes and crosspieces, precisely like that of *Dolichoderus bispinosus* (fig. 18, the colored parts), while the vegetable matter is entirely compact (without meshes) and more finely dismembered, though still recognizable in its structure (not pulverized); the walls of the nest are about half a millimeter thick.

Polyrhachis scissa ROGER, of Ceylon, builds its nest of exactly the same materials; but it is irregularly formed, and is attached to leaves rolled around galls, the crevices of which are closed with pasteboard.

I have received similar pasteboard nests of *Dolichoderus gracilipes* MAYR and of a species of *Cremastogaster* fixed upon leaves, from Ceylon, through Major Yerbury.

The nest of the *Polyrhachis jerdonii*[1] FOREL which I received from Ceylon through Major Yerbury is very interesting. This species builds upon leaves small nests, the wall of which greatly resembles in appearance the shell of many *Phryganeidæ* larvæ. Pebbles, and especially small fragments of plants, are cemented together by a fine web or woven together, and form a rather soft and tough web-like nest wall of a bright greyish-brown color. Fig. 17 gives a microscopic picture of this nest wall. We see here unmistakable small fragments of plants (Schol.) bound together in a web by peculiar silk threads (Gesp). These silk threads are found, upon a closer examination, to be of very irregular thickness, often branching, and in many cases issuing from a thicker crosspiece. Upon calling in the aid of the still more magnified web of *Polyrhachis dives* SM. (also from the East Indies), in fig. 7, there can be no doubt that a viscous substance secreted by the glands, similar to that which we have seen used as glue by the ants previously described, is here simply drawn out into threads. In fig. 7 are seen the thicker crosspieces of a still more shapeless mass of cement and the more finely spun threads drawn transversely out of them.

Polyrhachis dives, however, no longer needs any foreign material. It makes its nest wall out of pure silk web, exactly like coarse spun yarn or the web of the caterpillar. The web is of a brownish yellow, and is fixed between leaves, which are lined with it and bound together. Mr. Wroughton, of Poonah, India, sent me such a nest, simply between two leaves.

A still finer, softer silk web, finer and thicker than the finest silk paper, very soft and as pliable as the finest gauze, though much thicker, of a brown color, is produced by *Polyrhachis spinigera* MAYR. Fig. 16 presents a microscopic picture of it. Here we find no more crosspieces, but only silk threads. They are, however, still irregular, of varying thickness, spun across each other into a web. This web is fixed in a wonderful manner in the ground, where it forms the lining of a funnel-shaped cave, which is widened out into a chamber at the bottom. The honor of the discovery of this highly interesting nest is due to Mr. Wroughton; he found it in Poonah, India. Mr. L. Schröter made the somewhat schematic drawing of the nest, in its natural position, from

[1] *Polyrhachis jerdonii* (workers) n. sp. 4½ millimeters in length, short and broad; related to the *Polyrhachis argentea* MAYR, but still shorter, without silvery down, with a much less arched thorax sharply edged at the side, the abdomen sharply edged in front, with red mandibles, antennæ, and legs (except the tarsi). The other parts are of a dull black, thickly and irregularly punctate-reticulate, and with very fine, yellow, sparse, recumbent, and almost no erect hair. The head is wider than long, and broadens out very much behind. The clypeus is short, without flaps in front, not carinate; the laminæ diverge behind. The scape of the short frontal antennæ is somewhat in the shape of an S, and hardly extends beyond the back of the head. Scales between the spines, with a convex, emarginated upper border. Spines just like those of *Polyrhachis argentea*. The sculpture of the head is like the meshes of a net, with a dotted background. The body is dotted like a thimble.

an original sketch by Mr. Wroughton (fig. 8). We refer the reader to the drawing and to the explanation of the plates.

The large nest constructed in the foliage of trees, between the leaves, by *Œcophylla smaragdina* FABR., one of the most common ants of tropical Asia and tropical Africa, forms, however, the prototype of spun ants' nests. A great number of leaves are fastened together by a fine, white web, like the finest silk stuff. This web, apart from the color, has exactly the same appearance, both to the naked eye and under the microscope, as that of *Polyrhachis spinigera*. The leaves are usually fastened together by the edges. The nest is large, and the large, long very vicious, reddish to greenish worker ants live in it, with their grass-green females, their black males, and their whole brood. They form very populous colonies in the branches of the trees. Fig. 10 represents a portion of the nest of *Œcophylla smaragdina*, with the web and the borders of the leaves which are fastened together.

Now, how do the ants spin? This has, unfortunately, so far as I know, never yet been observed sufficiently closely. Not even the way in which the pasteboard of our European ants is made has been discovered. *Lasius fuliginosus* has never consented to work before my eyes. At all events, the spinning of *Œcophylla*, which works in broad daylight, ought to be the first to be seen, and, in fact, the only minute observations on this subject known to me, by E. H. Aitken, in the Journal of the Bombay Natural History Society, 1890, Vol. V, No. 4, page 422 ("Red ants' nests"), now lie before me.

Aitken saw how *Œcophylla* fastened two leaves together. A worker went to the base of the two leaves, at the point at which they began to separate, placed his hind legs, which are furnished with sharp claws, upon one of the leaves and drew the other leaf toward him with all his might with his upper jaw. If the distance was too great, from two to five ants chained themselves together for this task, each grasping the body of one of the others, the first holding one leaf with his mandibles, the last seizing the other leaf with the claws of the tarsi. While the edges of the two leaves were held as close together as possible, simply by these chains of ants working side by side, with the application of all their strength in the utmost tension, as if by india-rubber bands, Aitken saw other ants zealously engaged in binding the edges of the two leaves together with strong silk threads or ropes, which they spun closer and closer together the nearer the leaves approached each other. When a sufficient number of leaves had been fastened together in this way by their edges, the whole was rendered waterproof by a compact silk web, and was divided into chambers and passages by a similar web. Aitken is a reliable and accurate observer. This highly interesting observation of his is entitled to full credit. Only one thing is wanting to it, to wit, the information from what part of the body of the ant the silk thread issues. This must likewise be observed.

In my opinion, however, there is no doubt that the silk thread of *Œcophylla* and of the spinning species of *Polyrhachis*, like the cement of the other species of *Polyrhachis*, many of *Cremastogaster* and *Dolichoderus*, *Lasius fuliginosus*, etc., is formed from the so-called mouth saliva, and most probably from the secretion of the glands of the upper jaw. The cells of these glands, at least in *Œcophylla*, are large and numerous.

6.—SYMBIOSIS AND KINDRED RELATIONS BETWEEN ANTS AND PLANTS.

By symbiosis, in the more restricted sense, is meant the mutual services of two organisms living together, which, by a defensive alliance in the struggle for existence, are so dependent upon each other that the one can not thrive well without the other. The formation of special morphological characteristics is usually combined with genuine symbiosis. There are, besides, all possible forms of imperfect symbiosis, displaying transitions to parasitism, etc., above all, however, those in which only one of the two organisms is really dependent upon the other. For example, the small beetles *Lomechusa* and *Atemeles* can not live without their ant host. On the other hand, the ant can exist very well without such guests, and merely eats the secretion from the hair clusters of the beetles as a dainty (see Wasmann's elegant Observations on the Biology of the Guests of the Ants). There are, however, cases of still more imperfect, counterfeit symbiosis, where one organism entirely ignores the other, and, lastly, casual relations which are erroneously regarded as symbiotic.

The relations of certain ants to certain plants give rise to very peculiar forms of nests, of which we will speak briefly.

(a) *Genuine symbiosis.*—Dr. Fritz Müller, of Blumenau, South Brazil, has discovered the real relation of the *Cecropia* trees (the imbauba of the Brazilians) to *Azteca instabilis* SMITH. The ant genus *Azteca* FOREL, which is related to *Liometopum* MAYR, contains several American species, but the biology of *Azteca instabilis* only is known. Prof. A. F. W. Schimper (The Varying Relations between Plants and Ants, Jena, 1888) has given us in his excellent work his own observations in South Brazil, which substantially complete those of Müller.

Azteca instabilis lives only in the hollow trunks of certain species of *Cecropia*, especially *Cecropia adenopus*, which trunks are divided into chambers by transverse compartments; but Schimper has discovered a species of *Cecropia* on the Corcovado, which never contains ants, while *Cecropia adenopus* and others, as soon as they have grown somewhat large (1 year old), are always inhabited by *Azteca instabilis*. The following is now further ascertained:

The pregnant females of *Azteca instabilis* seek out for themselves a certain very thin and soft spot in the trunk of the *Cecropia*, which always has the same situation in every internode, bore into it, and thus get into the hollow, where they deposit their brood, if they are not

attacked by parasites (ichneumon flies). The opening then closes, but is subsequently opened again by the worker ants. This thinned spot is an adaptation of the plant to the ant; it does not occur in the *Cecropia* which is free from ants (that is to say, the corresponding bud depression is not changed in texture and is not atrophied). On the underside of the stem of the leaf of *Cecropia adenopus* and others is a peculiar hair cushion, which is constantly secreting albuminous, egg-shaped particles (Müller's corpuscles). These secretions are eagerly collected and devoured by the *Azteca;* they are one of their chief articles of food (ascertained through Fritz Müller). The *Cecropia* which is free from ants has none of Müller's corpuscles. The species of *Cecropia* are much frequented in Brazil by the leaf-cutting ants (species of *Atta*) and are terribly injured by them, as has been repeatedly ascertained by Belt and others. All those which contain *Azteca* colonies are spared, because the vicious *Azteca* pursue the *Atta* furiously and drive them away.

All this is well ascertained. The plant, by an undoubted adaptation, gives the ant food and lodging. The ant, in return, defends the plant from its worst enemy. This symbiotic relation did not, of course, arise all at once. Schimper found a *Cecropia* which is not inhabited by the *Azteca* until later, and probably also less regularly. This *Cecropia* has also, it is true, thinned boring spots, but they are not formed until later, and it has not as yet any Müller's corpuscles. Last year in Bulgaria I watched in oak woods and in old trees in general *Liometopum microcephalum* Pz., of Europe, which lives in trees. The trunks of the trees are there, too, covered with ants, which attack fiercely all that approach them. We have not in Europe any species of *Atta* that cut leaves, but, on the other hand, we have so many more beetles and other insects which delight to destroy the old oaks. I was charmed at seeing near Aetos the finest oak forest that I have ever beheld, with real, superb giants. Almost all of them were inhabited by *Liometopum* colonies, whose running workers covered all the trunks of the oaks. I have no doubt that these fierce ants, whose carnivorous habits Emery has described, drive away the enemies of the oak. The symbiotic relations of the *Azteca* and the *Cecropia* were probably formed from these simpler relations. *Liometopum* lives only in trees; the trees, however, do not display the least adaptation to that ant.

Belt and Schimper have further proved, as to *Acacia sphærocephala* WILLD. and *A. spadicigera* CHAM. and SCHLECHT, of Central America, that ants of the genus *Pseudomyrma* LUND not only always live in the hollow thorns, but, owing to a peculiar adaptation of that plant greatly resembling that of the *Cecropia*, find sugar and albuminous food upon them. These two species of *Acacia* possess so-called extrafloral nectaries, which furnish the ants with sugar, and on the points of their leaves Belt corpuscles rich in albumen (resembling the Müller corpuscles of the *Cecropia*), which supply them with albumen. Still a closer direct obser-

vation of the reception of the food by the ants is as yet wanting here. The *Acacias* which are free from ants do not possess these peculiar arrangements.

(b) *Imperfect symbiosis.*—Belt has ascertained that the species of *Pseudomyrma* which inhabit *Acacia* thorns are fierce, warlike creatures, and keep every foe at a distance from the plant, including the leaf-cutting *Atta*, the forest destroyers of America. The adaptation of the ant to the plant is ascertained as soon as it is proved that the respective species always lives and can thrive only in the corresponding plant. This has recently been sufficiently demonstrated in the case of *Pseudomyrma flavidula* and *Pseudomyrma belti*. With all this, however, it is not yet proved that all *Acacias* inhabited by ants contribute anything on their part to this arrangement. In fact, this is not yet proved in the case of many species; in others, it is very doubtful or improbable, because, on the one hand, there are many hollow *Acacia* thorns without ants (Mr. Wroughton has sent me such from India), and because, on the other hand, many species of ants of the genera *Pseudomyrma*, *Sima*, and *Cremastogaster* frequently inhabit these thorns, and frequently make their nests in some other way. These hollow thorns with the round aperture, which the ants make use of, and which are very similar in appearance to that of the gall in fig. 1, have been often depicted, and we do not, therefore, think it worth while to reproduce them here. I found a thorn of *Acacia fistula*, which had been brought from Somali Land by Prof. C. Keller, and which was inhabited by *Cremastogaster chiarinii* EMERY, divided inside by pasteboard into a few small chambers. In the case of *Cremastogaster chiarinii* EM., *C. acacia* FOREL, and *C. ruspolius* FOREL, there appears to be an adaptation of the ant to the plant.

We must now speak of the celebrated pseudobulbs of the epiphytic plants of the genera *Myrmecodia* and *Hydnophytum* of the Sunda Islands. Fig. 14 represents, in half the natural size, the photographed cross section of *Hydnophytum montanum*, which, with other magnificent specimens of this plant and of its relative, *Myrmecodia*, which has often been sketched, was sent to me recently from Java through the kindness of my friend and colleague, Dr. Ad. Frick, of Zurich. The enormous bulb of this plant, which lives as a parasite upon trees, is always pierced by a hollow labyrinth, as represented by the cross section in our figure. Now, this hollow labyrinth, according to the observations of Forbes, Beccari, Treub, and others, as well as that of *Myrmecodia*, is always inhabited by ants, which issue from little openings near the point of departure of the roots and fiercely attack every one who approaches, so that the natives are very unwilling to fetch these plants. Three species of ants, *Iridomyrmex cordatus* SMITH, *Cremastogaster deformis* SM., and *Pheidole javana* MAYR, were found in *Myrmecodia* and in *Hydnophytum*. While, however, *Iridomyrmex* seems to make its appearance always in these plants only, *Pheidole*

javana is very widespread in the Sunda Islands, and makes its nests in other ways besides. Emery is, therefore, of the opinion, which is doubtless correct, that *Pheidole* merely robs the nests of *Iridomyrmex* occasionally and is not adapted to the plant. On the other hand, Emery regards *Cremastogaster deformis* as the constant guest of the *Hydnophytum*. In all the Myrmecodia and Hydnophytum bulbs that I received in alcohol through Dr. Frick there was a colony of the smaller, darker Javanese variety of *Iridomyrmex cordatus* SMITH (Var. *Myrmecodiæ* EMERY), including males, a few pregnant females, and numerous larvæ and pupæ. All the specimens of the plant had the same hollow labyrinth, looking like a nest built by ants. It must be added that the genus *Iridomyrmex* is very closely related to *Azteca* and *Liometopum*, but comprises many species which build nests of earth.

Now, Treub has ascertained (Annals of the Botanical Garden of Buitenzorg, Vol. VII, 1888, p. 191) that Myrmecodia raised from seeds in hothouses and in the botanical garden of Buitenzorg develop the whole hollow labyrinth in their bulbs, to complete maturity, without the presence of ants, just as well as those which, in a state of freedom, possess ants. At the same time the plants thrive admirably. This proves that the labyrinth is produced by the plant, and not by the ants, though Beccari repeatedly found severed bundles of vessels in the compartments. Treub has, consequently, resorted to other attempts at an explanation, and has regarded these singular cavities as the breathing organs of the plant, and connected them with the interior irrigation of their web (the compartments have a very watery web), which, in view of the epiphytic situation of the plant upon trees with little foliage, is plausible. My own opinion, however, is that Beccari's observations are correct, and that the ants lend their aid by connecting some of the cavities by bored passages, as the natural cavities do not all appear to me to have a natural communication with each other, such as the ants require. Furthermore, the founders of the colony, the mother females, must first bore in. At all events, only the adaptation on the part of the ant is well ascertained—that is to say, in the case at least of *Iridomyrmex cordatus*, which finds its exclusive, beautiful, and secure dwelling in the plants of the genera *Myrmecodia*, *Hydnophytum* (and *Dischidia*?). Botanists say that these plants furnish no special food to the ants, at least nothing has been found corresponding to the Müller's corpuscles of *Cecropia*. Since, however, most of the *Dolichoderi* keep no plant lice, but lick up the secretions of plants, or devour insects, a closer investigation of the mode of feeding of *Iridomyrmex cordatus* would probably bring some interesting facts to light. Besides, Treub's observations do not prove by any means that the plant does not form the labyrinth for the purpose of serving as a dwelling for the ants. The fierce inmates certainly afford it protection against its enemies. We must investigate, as Schimper did for *Cecropia*, whether there are kindred species of plants, not inhabited by ants, with or without similar

labyrinths. It remains surprising enough, in spite of Treub's later explanation, that so small a plant forms such a colossal bulb, with such cavities, to which a particular species of ant has so evidently adapted itself. It seems to me that the possibility of an adaptation on the part of the plant can not yet be decisively denied, and that we should await further investigations into the biology of *Iridomyrmex cordatus* and *Cremastogaster deformis*. The fact that in the botanical garden at Buitenzorg Myrmecodia thrives without *Iridomyrmex* (Treub) proves nothing, because, in the first place, the conditions of the struggle for existence are entirely different there from those of the primeval forest; and, in the second place, because other ants frequently take possession of their dwellings in the Myrmecodia bulbs, and act as their representatives. Treub found no dangerous foes of Myrmecodia in the botanical garden, but in the forest it can be eaten or otherwise destroyed by mammals or other animals which are kept at a distance by the ants. Skepticism is necessary and good, but denial and rejection are not good without sufficient reasons.

In a shrub in Borneo, *Clerodendron fistulosum* BECCARI, Beccari constantly found a *Colobopsis*, which Emery has named *Colobopsis clerodendri*. Here the plant, which, like the *Cecropia*, has hollow internodes, likewise forms a round attenuated spot in its walls, which is bored through by *Colobopsis*, and serves it as a door. The plant also possesses innumerable extrafloral nectaries (that is to say, glands producing a sugary liquid, which lie, not in the flowers, but in other places). Still, I am not yet entirely convinced, in this case, that there is an adaptation on the part of the plant, because the species of the genus *Colobopsis*, so far as hitherto known, are shy and cowardly, and would, consequently, furnish no protectors to the plant. The similarity of the shape of the head of the soldier of this species seems to me to indicate that he stops up the round opening of the nest in the stalk of the Clerodendron, with his head, in the same manner that the soldier of our European *Colobopsis truncata* stops up the door of his wood nest. All investigations on this subject, as well as on the ant's mode of feeding, are still wanting.

There are, besides, a number of similar incomplete or doubtful relations, noticed especially by Beccari, as, for example, that of the palms of the genus *Korthalsia* to *Camponotus hospes* EMERY and *korthalsiæ* EMERY; that of plants of the genus *Triplaris* to various ants which inhabit their stalks, etc.; but minute investigations of them are still wanting. The future will yet bring us many surprises.

(c) *Casual relations.*—We have already become acquainted with these in that kind of nest in which the ants make use of natural cavities. Hollow acacia thorns are also frequently used as dwellings by ants which elsewhere make their nests in an entirely different way. Thus, Mr. Wroughton once, in an exceptional case in India, found *Sima nigra* JERDON living in an acacia thorn.

7.—COMPOUND NESTS.

In the Communications of the Swiss Entomological Society, Vol. III, part 3, 1869 (Observations on the habits of *Solenopsis fugax*), I first called attention to the fact that two hostile species of ants can live in nests which are regularly intercalated. In my "Fourmis de la Suisse" (1874), I showed that such relations occur very frequently and more or less accidentally among many species of ants, especially under stones that are well adapted to nests and greatly in demand; while, in *Solenopsis fugax* LATR., "double nests" form a very ordinary, in fact, the most ordinary, occurrence, at least in our meadows. Wasmann (The Compound Nests and Mixed Colonies of Ants, Münster i, W., 1891, Aschendorff's) has corroborated and supplemented my observations on this subject. Instead of the name "double nests," used by me, he has introduced the more correct expression "compound nests" (to be translated into French by "nids composés"). In fact, these nests are not unfrequently threefold, and even fourfold—that is to say, the nests of from three to four different and hostile species of ants are built into each other, without, however, having any open communication with each other. If the partitions are destroyed, war ensues immediately. The worker of *Solenopsis fugax* is a puny, yellowish ant, hardly 2 millimeters in length, but the females grow to an imposing size, and look like giants by the side of the workers. This species is in the habit of digging its nests in the thick walls of the nests of the ants of the larger species, and in such a manner that, wherever there is room, large halls are constructed (fig. 6, S), in which the females and the males are comfortably lodged with their large pupæ and larvæ, while small passages connect these halls. Extremely small passages, not visible in the figure, afford the workers exclusively admission to the chambers of the host ant (fig. 6, For). According to my observations and those of Wasmann, *Solenopsis fugax* lives like a thief and little robber, at the expense of its involuntary host. The little workers make their way through extremely small passages to the pupa and larva heaps of the large ants and devour them from underneath without being seen, thanks to their small size. They also devour openly the forage supplies, as well as the dead and sick individuals, of the larger species (mostly *Formica fusca* L., but also *Formica rufa*, *F. pratensis*, *F. sanguinea*, *Polyergus rufescens*, *Lasius niger*, etc.).

Fig. 6 represents a fragment of a double nest of *Formica fusca* and *Solenopsis fugax* from the Zurich Mountain. By means of dissolved shellac, which I poured upon the nest in fine weather, and then allowed to dry, I succeeded in making it firm enough to be able to take it out without injuring it. The fine-grained, polished interior walls of the *Solenopsis* cavities are seen, in contrast to the coarse-grained and more spacious *Formica* chambers. As the ants take up the moist earth with their mandibles in the form of small lumps, and then work it into shape with their jaws and forelegs, in order to construct their masonry with

it, and as, moreover, the large *Formica* works with much coarser particles than the puny *Solenopsis*, the different character of the walls is at once explained.

I have already explained the frequent occurrence of imperfect, more accidental compound nests of other species of ant, by ascribing them to the acquisition of favorable localities, especially the underside of stones. From this competition frequently arise very murderous underground wars, which I have often watched. I have noticed closely, in glass apparatus, how they are carried on. The ants mine toward each other. A battle begins where their work happens to meet. The conqueror forces his way into the gallery of the conquered. The latter, however, hastens, after he has retired a few millimeters or centimeters, as the case may be, to stop up his gallery thoroughly with earth. The victor does not then, by any means, always succeed in again finding the entrance to it, but, in many cases, mines by the side of it, and thus partial interlappings of the nests arise. The galleries of *Solenopsis fugax* are often broken through by the large ants. The little robbers are, however, in the first place, very courageous and combative; and, in the second place, they know how to mine rapidly and how to barricade rapidly, and by this means to make a skillful use of all the partitions, as I have been enabled to observe directly in the glass nest. The digging and fighting spirit is at its highest pitch among the ants in the first half of the summer, when the nests have to be enlarged for the brood. It then ceases, and truces follow; in the autumn there is abundant space for all, and peace prevails. It is not without reason that the females and males of *Solenopsis fugax* do not swarm until September, when the swarming time of their host ants (July=August) has long been past. They can then, in spite of their size, go to the upper surface of the nest and swarm undisturbed, as I have seen myself, whereas they could not have done so earlier without great danger.

A peculiar variety of the compound nest is formed by the dwelling of the guest ant *Formicoxenus nitidulus* NYL., with *Formica rufa* and *Formica pratensis*, which I first discovered in a fragmentary condition, and which Adlerz subsequently found and described more fully. *Formicoxenus* hunts the large *Formica*, and even follows it up closely throughout its changes of abode, as Wasmann first noticed, and as I have verified. By *Formica*, on the other hand, it is merely tolerated and superciliously ignored. The peaceable guest constructs in the walls of the nest of its large host ant little chambers and passages, which are, however, only imperfectly closed, and open freely into the chambers of the *Formica*. In these little chambers lie the brood of the *Formicoxenus*. The *Formicoxenus's* mode of subsistence is still unknown.

8.—NESTS OF MIXED COLONIES.

The mixed colonies of the slaveholding ants and parasite ants (*Polyergus rufescens* LATR., *Strongylognathus testaceus* SCHENK and *S. huberi* FOREL, *Anergates atratulus* SCHENK, *Xenomyrmex stollii* FOREL) have

nests which always display the architecture of the working ant (slave or host), and have no further interest for us here. When *Polyergus rufescens* seizes *Formica rufibarbis* and keeps it as its slave, its nest resembles a larger nest of that species; if, on the other hand, it enslaves *Formica fusca*, its nest looks like the nest of *Formica fusca*, because the so-called slave or auxiliary ants are the only builders.

The case appears to be somewhat different in the rare, natural, fortuitous mixed colonies (*Formica pratensis* or *truncicola* or *exsecta*, with *Formica fusca; Tapinoma erraticum* with *Bothriomyrmex meridionalis*) discovered by me (Fourmis de la Suisse), as well as in *Formica sanguinea* LATR., which almost always keep slaves, but notwithstanding also work themselves. Here the nest assumes a mixed architecture, as both species of ant work on it, each in accordance with its instinctive art. And yet they do not interfere with each other. Each species understands how to combine its work harmoniously with that of the other, although the methods of the two are often very different, as, for instance, with the mason ants, *Formica fusca* and *Formica pratensis*, which work more like carpenters with their little branches and crosspieces. *Fusca* unites the wooden rafters of *pratensis* by means of moist earth, and the whole lasts very well. I have also caused many artificial mixed colonies to be founded between *Formica sanguinea* and *F. pratensis*, etc., have even discovered naturally established colonies of these two latter species, and have investigated their mixed architecture.

9.—MIGRATORY NESTS.

Belt (The Naturalist in Nicaragua, 1874) was again the first to discover the hitherto unknown nest of the American migratory ants (*Eciton*). He found in the forest an immense ant ball, from which all the robber columns issued, and in which all the brood lay. Here was a genuine nomad nest, a living nest without a house. Sceptical as we had been with regard to the other discoveries of the genial Belt, we remained so respecting this one, too, until I succeeded, in the year 1885, in interesting Fritz Müller's younger brother, Dr. Wilhelm Müller, who was residing at that time at Blumenau with his brother, in this question. Dr. W. Müller has published the results of his very interesting observations in the first volume of Kosmos (1886, p. 81: Observations on Migratory Ants). That which bears upon our subject may be summed up as follows: The larger species of *Eciton*, which have eyes (*hamatum* F., *foreli* MAYR, *quadriglumis* HALID. [=*legionis* SM. =*lugubre* ROGER], etc.) do not build or excavate any nests. They live a wandering life and merely occupy with their extremely numerous colonies spacious, naturally sheltered places, such as hollow trees or shrubs, in which they live rolled up together in immense clusters (one cluster of ants and brood, measured by Dr. W. Müller, which did not compose half the colony, measured in an etherized state 5,600 cubic centimeters). The larvæ and pupæ first collected by Dr. W. Müller and examined by me

lie at liberty among the ants, and are carried by them. The robbing expeditions are undertaken in the daytime, and the booty is carried to the migratory nest, where it serves chiefly as food for the larvæ. When one locality has been sufficiently pillaged the whole colony migrates to another resting place. These latter migrations with bag and baggage, that is to say, with the brood, take place exclusively at night.

Far less is known about the nests of the blind species of *Eciton* and the entirely blind migratory ant genera *Dorylus* and *Ænictus*, whose workers had previously, like the male of *Eciton* (*labidus*), been classed as separate genera (*Typhlopone* WESTW. and *Typhlatta* SMITH), because their connection with the previously described males was not yet known. I have myself seen *Dorylus juvenculus*, at Gabés, South Tunis, hunting under ground. The winged males of *Dorylus juvenculus* FAB. (*badius* GERST.), *Eciton hetschkoi* MAYR, and *Ænictus wroughtonii* FOREL have been seen creeping out of the ground in company with workers and flying away. The very nest of *Dorylus helvolus* was dug up by Trimen, who found the female. Nothing more definite, however, is known. Are the plundered nests of other ants used for the moment as migratory nests? Are there here nocturnal migrations, too, and not robbing expeditions only? The future must tell us. At all events, judging by the observations made up to this time, including my own, *Dorylus* and *Ænictus* appear to prefer the neighborhood of human habitations, and to fight under ground with other ants.

10.—ROAD BUILDING.

Certain European ants, *Formica rufa*, *F. pratensis*, and *Lasius fuliginosus*, build genuine roads in our meadows. The finest and best finished are those of *Formica pratensis* DE GEER. A meadow, as has already been said, is a primeval forest to the ants. If the ants are like *Formica pratensis*, rather large, and if they are compelled, like that species, to drag home all kinds of timbers as building materials, as well as animal booty, a meadow, which otherwise furnishes them with the finest hunting grounds, presents terrible obstacles. *Formica pratensis* is awkward; we need only notice what inexpressible difficulty it has in making its way with a load through the thicket of blades of grass in a meadow, how constantly the load is getting wedged between them, and what incredible patience and perseverance the insect displays in the effort to go forward to understand the object of the roads. The road building of *Formica pratensis* presents one of the most wonderful displays of animal instinct that I know of. Several such roads radiate with great regularity from one of the larger nests of this species lying in a meadow; I have counted from three to eight and even twelve of them (so large a number is rare and occurs only in the case of very large nests). It can be seen that these roads lead mostly to trees or shrubs on which the ants climb up in multitudes in order to milk the plant

lice. The road itself is kept very clean, is from 2 to 4 centimeters in width, and is made more or less concave laterally. Not only is no movable object allowed upon it, not only is it kept always clean and in good order, but the ants, with the expenditure of incredible toil and strength, saw off with their mandibles every blade of grass that attempts to grow in the road, as they previously sawed off all those which were in existence when it was first constructed. Where the tufts of grass are too thick and strong, they go around them, it is true; but the roads usually run comparatively straight to their destination. Many of them are gradually lost in the grass; but as a rule they can be followed to a distance of 20, 30, 40, and in many cases 50 meters from the nest. One must watch long, closely, and above all in the spring, to see and understand the road building, and to avoid the impression that the road, as certain authors have thought, comes into existence of itself through the footsteps of the ants. These roads are very numerously frequented. All the building materials and forage are first dispatched to the nearest road, so that they may be carried comfortably from there to the nest. As *Formica pratensis* has very defective powers of smell, and is not skillful in finding its way, the roads are also of great advantage to it in this respect. There are only two directions on them, and it is no longer compelled to search laboriously for the right way. It can be seen, too, how rapidly and confidently the ants move to and fro on their roads, in contrast to their behavior in the grass. (Compare Forel: Collections of Swiss Zoology, Vol. IV, No. 4, 1888.)

The agricultural ants of Texas (*Pogonomyrmex barbatus* SMITH, *P. molefaciens* BUCKLEY) make a large clearing around their nests, according to Lincecum and MacCook, and numerous roads, in addition, by sawing off the blades of grass, like our *Formica pratensis*.

11.—REVIEW—THE ANT WORLD—LANDSCAPE TYPES OF THE ANTS' NESTS—POLYCALIC COLONIES.

Even among us in Switzerland, a close investigation of the meadows, the dry declivities of the mountains, the clearings of the woods and thickets suffices to show us speedily that almost everything is invaded by the structures of ants. Where there are no actual nests there are underground passages and galleries, open roads, covered ways, or, at least, the inhabitants of neighboring nests, who are scouting around and contending with one another for the possession of the plants containing plant lice and cochineal kermes, of the trees, the flowers, and the insect plunder. I have even seen young birds which had just slipped out of the nest killed and devoured by *Formica pratensis* in spite of the frantic rage of the parent birds. The ants certainly, no less than men, fancy themselves the lords of creation, for, thanks to their social organization, their numbers, and their courage, they have few foes to fear; their most formidable enemies are always other

ants, just as men are for other men. In the tropical world the struggle for existence is much fiercer than with us, and the ants, with their immense number of species, play a much more important part. Their nest structures there, too, are correspondingly far more varied, and display far more singular and complicated adaptations as the results of the fight for life. The future will develop many still more astonishing discoveries.

We will now only give a glance at the most ordinary ant structures with respect to the nature of the ground.

In the meadows we find, above all, the mound structures of earth, but side by side with them the mixed mounds of *Formica pratensis*, *sanguinea*, and *pressilabris*, together with pure excavated nests. On detritus and declivities, we find chiefly nests under stones, and the same upon mountains generally. In the forest we find the mighty mounds of *Formica rufa*, *exsectoides*, and *exsecta*, frequently gathered into large, united kingdoms, containing many nests (polycalic colonies), and also the tree nests of *Lasius fuliginosus*, *L. brunneus*, *Camponotus herculeanus*, *Liometopum microcephalum*, etc. Genuine, that is to say free, tree nests of pasteboard or web in the boughs of trees do not occur in Europe. Lastly, in the forest clearings, the edges of the woods, and in thickets we find a rich mixture of the three above-named landscape types with respect to ants' nests. The meadow type, the forest type, and the detritus or declivity type are here mingled pellmell.

The nest structure in the desert, as I have been enabled to learn by observation in southern Tunis, forms a peculiar type. There all is excavated in the sand. There are neither mounds nor stones, but at most hillocks of sand around the openings of the nests.

My object has been merely to give, by the aid of drawings, a clear view of our present knowledge of the nest building of the ants and to communicate some new facts in connection with it. I trust that I have succeeded.

To conclude, it is a pleasure to me to express my warmest thanks to my friend Mr. Ludwig Schröter for his successful drawings; to Professor Schröter for his kind assistance, his suggestions, and his advice; and to the persons who procured me my excellent materials, especially my friends, Mr. Wroughton, Dr. Frick, Professor Emery, Dr. Liengme, and Professor Mayr.

EXPLANATION OF PLATES LV, LVI.

Fig. 1. A gall, inhabited by *Polyrhachis gerstäckeri* FOREL, from Delagoa Bay, South Africa; collected by Dr. Liengme. One-sixth less than the natural size.

A. The gall from the outside; op., the egress opening of the gall producer, used by the ants.

B. Longitudinal section through the gall, showing the cavity and its filling of web and a half partition.

Fig. 2. Longitudinal cross section of the stalk of *Solanum auriculatum*, from Antananarivo, Madagascar, inhabited by *Technomyrmex albipes* SMITH; collected by Père Camboué. The marrow of the stalk has been divided by the ants into chambers. Two-thirds natural size.

Fig. 3. A leaf of *Eugenia jambolana*, the cellular tissue of which, between the two surfaces, has been eaten out by a worm, and which has then been inhabited by *Cardiocondyla wroughtonii* FOREL. Collected at Poonah, India, by Mr. Wroughton. Two-thirds natural size.

Fig. 4. Pasteboard nest of *Polyrhachis mayri* ROGER, half open, showing the interior; resting upon a leaf. From Ceylon; collected by Major Yerbury. Two-thirds natural size.

Fig. 5. A nest of *Leptothorax acervorum* FAB., excavated in the cork layer of the bark of a fir; spread out flat. Cross section along the plane of the nest; an opening at *a*. From Switzerland. Two-thirds natural size.

Fig. 6. Piece of a double nest of *Formica fusca* L. and *Solenopsis fugax* LATR., collected by me near Zurich and preserved by impregnation with shellac. Two-thirds natural size.

W. The plane of separation in the walls of the nest of *Formica*.

For Excavations of *Formica fusca* (recognizable by the coarser grain and the greater width).

S. Excavations of *Solenopsis fugax*, made in the walls of the nest of *Formica*, recognizable by the fine grain.

S. o. Openings of the passages which connect the larger chambers of *Solenopsis*.

Fig. 7. Web of *Polyrhachis dives* SM., from the East Indies. Microscopic enlargement; Hartnack, System IX.

Fig. 8. Nest of *Polyrhachis spinigera* MAYR, from Poonah, India; from a sketch by Mr. R. C. Wroughton, divisional forest officer at Poonah. The nest lies under a stone and is excavated in the ground, but is lined with a fine web, as Mr. Wroughton has repeatedly verified. The figure represents an imaginary cross section, somewhat smaller than the natural size.

St. The stone.

Gr. The ground.

W. The web.

Op. The opening for ingress and egress.

Cell. The nest excavation.

Fig. 9. Fragment of the mound of a ground nest of *Lasius niger* L., from Zurich. We see how blades of grass and leaves are used as pillars, arches, etc., in the masonry. Two-thirds natural size.

Fig. 10. Nest web of *Œcophylla smaragdina* FABR., received from India, through Mr. Wroughton. We see from this fragment how the leaves of a tree are united into a nest by means of the web. W., the web. Two-thirds natural size.

Fig. 11. Flat surface of the head of a soldier of *Colobopsis truncata* SPIN., from Vaux, Canton Waadt, Switzerland, seen from the front, and magnified ten times.

Man. Upper jaw.

C. Cheeks.

F. Forehead.

Fig. 12. Perpendicular cross section of the nest of *Tapinoma erraticum* LATR., from Vaux, Canton Waadt, Switzerland. Preserved by me by means of impregnation with silica. Two-thirds natural size.

D. Temporary mound of earth.

Int. Interior of the nest, with its natural framework of blades of grass.

Min. Beginning of the underground excavated part of the nest.

Gr. Cross section of the ground.

Fig. 13. Cross section of a fragment of a nest of *Colobopsis truncata* SPINOLA, excavated in the wood of a dead, but extremely hard, pear tree. Found by me at Vaux, Canton Waadt, Switzerland. Four-thirds natural size.

Ch. Excavations of the nest in the wood.

Fig. 13—Continued.

B. Bark of the bough of the pear tree.

O. Opening of the nest outward, and head of a soldier of *Colobopsis truncata*, who is guarding this opening, or, rather, who is keeping it closed with his head, as with a stopper. The soldier is standing in the egress passage, which is seen in cross section.

W. Two workers of *Colobopsis truncata*, one in the nest, the other outside, hurrying to the entrance, where the soldier, drawing back, will make room for him for a moment.

Fig. 14. Cross section of the pseudo bulb of *Hydnophytum montanum*, received from Java, through Dr. A. Frick, of Zurich. Photographed in one-third of the natural size. The stalk, the leaves, and the root of the plant are also seen (see text).

Fig. 15. Pasteboard nest of *Dolichoderus bituberculatus* MAYR, on the bough of a tree. Received from Bangkok, Siam, from the late well-known turner, Mr. Sigg, of Zurich. In order to show the interior labyrinth, a portion of the nest has been removed by a flat, perpendicular cut. Photographed in one-third of the natural size.

Surf. Surface of the cut and inner labyrinth.

U. s. Natural upper surface of the nest.

Br. A small branch of the main bough, cut through and inclosed in the nest. The nest rests upon the main bough.

Fig. 16. Web of *Polyrhachis spinigera* MAYR, from Poonah, India; received from Mr. Wroughton. Microscopic enlargement; Hartnack, System IX. (Compare fig. 8, Gesp.)

Fig. 17. Nest wall of *Polyrhachis jerdonii* FOREL, from Ceylon; received from Major Yerbury, through Mr. Wroughton. Microscopic enlargement; Hartnack, System VII.

Fl. Small flakes of vegetable matter.

Web. Spun net of the ants, by means of which these flakes are joined together in a web.

Fig. 18. A piece of the nest pasteboard of *Dolichoderus bispinosus* OLIV., from tropical America; received through Professor Emery. Microscopic enlargement; Hartnack, System IV.

Fib. Vegetable fibers (of *Bombax ceiba* L.) of which the nest pasteboard is composed.

Cem. Ant cement, or lac, by which the vegetable fibers are glued together or fastened (of a bright yellowish or brownish color).

Mesh. Empty meshes left by the nest walls between them.

Fig. 19. (See text, p. 487.)

N. B.—All the figures, except fig. 8, were drawn or photographed (figs. 14 and 15) from nature by Mr. L. Schröter. I myself drew only fig. 11 and the ants in fig. 10.

The originals of figs. 1, 2, 3, 4, 7, 10, 14, 15, 16, 17, and 18 are in my collection; those of figs. 5, 6, 9, 12, and 13 are in the entomological collection of the Museum of the Federal Polytechnikum (my former collection of European ants' nests).